We claim:

1. Mediated electrochemical oxidation (MEO) apparatus comprising an electrochemical cell including plural closed-loop systems, electrolytes in the closed-loop systems, and pumps coupled to the closed-loop systems for circulating the electrolytes in each of the plural systems.

2. The apparatus of claim 1, further comprising a membrane for separating the plural closed-loop systems into anolyte chamber and catholyte chamber in the cell permitting a user to change the electrolytes without altering the apparatus.

3. The apparatus of claim 2, further comprising an anolyte in the anolyte chamber and a catholyte in the catholyte chamber.

4. The apparatus of any of the preceding claims, further comprising a drain in each of the closed-loop systems for separately removing and/or replacing the anolyte and/or the catholyte in the apparatus.

5. The apparatus of any of the preceding claims, further comprising a device for monitoring the anolyte and/or catholyte chambers

6. The apparatus of any of the preceding claims, wherein the device is a camera for viewing progress in the anolyte and/or catholyte chambers

7. The apparatus of any of the preceding claims further comprising heaters coupled to the chambers for heating the anolyte and/or the catholyte.

8. The apparatus of any of the preceding claims further comprising chillers coupled to the chambers for cooling the anolyte and/or the catholyte.

9. The apparatus of any of the preceding claims, further comprising an off-gas processing system coupled to the cell for handling off-gases from the anolyte chamber and the catholyte chamber.

10. The apparatus of any of the preceding claims, further comprising a dewatering system coupled to the cell for removing water generated from the destruction of the materials or associated with its introduction into the units.

11. The apparatus of any of the preceding claims, further comprising tanks coupled to the cell for receiving and/or storing the water from the dewatering system for disposal and/or reconstitution of the electrolytes.

12. The apparatus of any of the preceding claims, further comprising a clean water pump coupled to the cell for pumping clean water into the anolyte chamber and/or the catholyte chamber for restoring levels of the anolyte and/or the catholyte.

13. The apparatus of any of the preceding claims, further comprising a controller system coupled to the cell for managing operational cycles of the apparatus.

14. The apparatus of any of the preceding claims, further comprising sensors integrated throughout the apparatus for sensing and relaying data about the apparatus.

15. The apparatus of any of the preceding claims, further comprising computing devices communicating with the apparatus for monitoring the apparatus, for receiving, analyzing, computing and outputting data relative to the apparatus, and for controlling operation of the apparatus relative to the data received, analyzed and computed.

16. The apparatus of any of the preceding claims, further comprising a flow meter coupled to the cell for measuring flow of the anolyte to and from the anolyte chamber, wherein outputs of the flow meter are used to monitor and assess status of the anolyte circulation.

17. The apparatus of any of the preceding claims, further comprising energy sources coupled to the cell for providing ultrasonic and ultraviolet energy to the anolyte chamber.

18. The apparatus of any of the preceding claims, further comprising material introduced into the anolyte chamber for treatment with the anolyte.

19. The apparatus of any of the preceding claims, further comprising thermal controls for controlling the temperature of the electrolytes to a desired temperature range to affect desired chemical reactions at desired rates.

20. The apparatus of any of the preceding claims, wherein the temperature is along a range at or below an operating temperature to a maximum desired operating temperature corresponding to a rate of destruction of materials and/or the order in which specific molecular bonds are broken.

21. The apparatus of any of the preceding claims, wherein the temperature range is approximately slightly above 0°C to slightly below the boiling point of the anolyte solution or slightly below 100°C.

22. The apparatus of any of the preceding claims, wherein the temperature of the anolyte chamber is most conducive to the desired materials destruction rate while the temperature of the electrochemical cell may be operated at the temperature most conducive to oxidizer formation.

23. The apparatus of any of the preceding claims, further comprising a power supply coupled to the apparatus.

24. The apparatus of any of the preceding claims, wherein the power supply is AC and/or DC power supply.

25. The apparatus of any of the preceding claims, wherein the power supply supplies electric current to the cell in a range between low operating concentrations to maximum desired operating concentrations for the materials.

26. The apparatus of any of the preceding claims, wherein the anolyte comprises an aqueous solution of mediator species and electrolytes appropriate for the species.

27. The apparatus of any of the preceding claims, wherein the electrolyte is selected from the group consisting of acid, alkaline, neutral salts, and combinations thereof.

28. The apparatus of any of the preceding claims, further comprising monitors for monitoring electrochemical and physical processes of the cell.

29. The apparatus of any of the preceding claims, wherein the monitors monitor cell voltages and gather information about the ratio of oxidized to reduced mediator ion concentrations which may be correlated with the amount of reducing agent either dissolved in or wetted by the anolyte.

30. The apparatus of any of the preceding claims, wherein the monitors include sensors to monitor the concentration of mediator ions, color changes accompanying transition of the mediator species between oxidized and reduced states, the rate of decay of the color associated with the oxidized state, under zero current conditions, being used as a gross indication of the amount of reducing agent present.

31. The apparatus of any of the preceding claims further comprising a mediator to serve as an oxidization potential equivalent of a pH indicator having an oxidation potential between that of the working mediator and the species, and a color change associated with the oxidization state transition.

32. The apparatus of any of the preceding claims further comprising ultraviolet light sensor to indicate that the ultraviolet source is functioning properly.

33. The apparatus of any of the preceding claims, further comprising a liquefier for emulsifying the materials introduced into the anolyte chamber thereby greatly increasing the area of contact between the materials and oxidizers during the electrochemical process and increasing the materials destruction rate.

34. The apparatus of any of the preceding claims, further comprising an injector for injecting new anolyte into the anolyte chamber if and as required.

35. The apparatus of any of the preceding claims wherein the injection operation is initiated by an operator and is controlled through the controller system.

36. The apparatus of any of the preceding claims wherein all surfaces of the apparatus in contact with the anolyte comprise one or more of the types of materials selected from the group consisting of nonreactive polymers, stainless steel coated with nonreactive polymers, glass, PTFE coated metallic tubing, glazed ceramics, glazed metallics, glazed composites, and combinations thereof.

37. The apparatus of any of the preceding claims, further comprising an air sparge coupled to the cell for introducing air into the catholyte chamber below the surface of the catholyte.

38. The apparatus of any of the preceding claims, further comprising a sensor for detecting and measuring air flow through the air sparge for oxidizing nitrites or nitrous acid produced by cathodic reduction and preventing formation of nitrogen oxides in systems using nitrate catholytes and for diluting and removing off-gas in systems using non-nitrate catholytes.

39. The apparatus of any of the preceding claims, further comprising enhancing devices for enhancing contact of the oxidizing gas with reduced nitrogen compounds for promoting gas/liquid contact.

40. The apparatus of any of the preceding claims, further comprising catholyte air intake and/or filter for allowing ambient air to enter the catholyte chamber and to exit to a catholyte off-gas handling system.

41. The apparatus of any of the preceding claims, further comprising a catholyte off-gas handling system for removing any unwanted gas products.

42. The apparatus of any of the preceding claims, further comprising a cleaner for cleaning the gas stream, and catholytic vent for discharging the cleaned gas stream and unreacted components of the air introduced into the system.

43. The apparatus of any of the preceding claims, further comprising an anolyte recovery system for removing mediator oxidizer ions to maintain process efficiency, cell operability, or if economic worth of the ions necessitates their recovery.

44. The apparatus of any of the preceding claims, further comprising operating the electrochemical cell at higher than normal membrane current densities increases rate of materials destruction.

45. The apparatus of any of the preceding claims, further comprising providing all surfaces of the apparatus in contact with the catholyte of acid and alkaline resistant materials.

46. The apparatus of any of the preceding claims, further comprising an anolyte reservoir coupled to the anolyte chamber.

47. The apparatus of any of the preceding claims, further comprising a dump valve for connecting the anolyte reservoir to the anolyte chamber and a lid on the anolyte chamber.

48. The apparatus of any of the preceding claims, wherein anytime the lid to the anolyte chamber is opened for access, the dump valve is opened prior to opening the lid such that the liquid contents of the anolyte chamber drops into the anolyte reservoir thereby avoiding potential contact of the anolyte with the user.

49. The apparatus of any of the preceding claims, further comprising a waste basket to hold solids in the anolyte chamber.

50. The apparatus of any of the preceding claims, further comprising anolyte air intake and/or filter for drawing air into the anolyte chamber and purged off gases through the anolyte off-gas handling system.

51. The apparatus of any of the preceding claims, further comprising sensors including an ultrasonic anolyte chamber sensor to measure amount of anolyte in the anolyte chamber, sensor to detect overfill, an ultrasonic sensor to measure the amount of anolyte in the anolyte reservoir and sensors to measure whether the anolyte reservoir is being filled beyond a recommended level.

52. The apparatus of any of the preceding claims, further comprising an input pump for introducing materials in continuous feed operations into the anolyte chamber and wherein the input pump is connected to a source of the materials to be destroyed, the materials are pumped into the chamber which contains the anolyte used to destroy these materials, and the apparatus continuously circulates the anolyte solution directly from the electrochemical cell through inlet tube into the anolyte chamber to maximize the concentration of oxidizing species contacting the materials.

53. The apparatus of any of the preceding claims, further comprising spray and/or stream head(s) for introducing the anolyte into the anolyte chamber for increasing exposure of

the materials to the anolyte by enhancing the mixing in the anolyte chamber and promoting contact with any immiscible materials present in surface layers.

54. The apparatus of any of the preceding claims, further comprising a filter located at the base of the anolyte chamber to limit the size of the solid particles flowing from anolyte chamber thereby preventing solid particles large enough to interfere with the flow in the electrochemical cell from exiting the anolyte chamber.

55. The apparatus of any of the preceding claims, further comprising enhancing devices for enhancing contact of the oxidizing species with solid or liquid immiscible liquid materials, or incomplete oxidation products that are solid, immiscible liquid, or gaseous at the conditions within the anolyte chamber.

56. The apparatus of any of the preceding claims, further comprising an ultraviolet source introduced into the anolyte chamber to decompose hydrogen peroxide formed by the MEO process into free hydroxyl radicals.

57. The apparatus of any of the preceding claims, further comprising an anolyte off-gas system for exhausting gaseous products resulting from the MEO process in the anolyte solution.

58. The apparatus of any of the preceding claims, further comprising a gas cleaning system for processing anolyte off-gas, and anolyte return for returning the anolyte to the anolyte pump in the anolyte system and the electrochemical cell where the oxidizing species are regenerated completing circulation in the anolyte system.

59. The apparatus of any of the preceding claims, further comprising a removal system for removing any oxidized insoluble compounds that form as a result of mediator or

electrolyte ions reacting with anions of or containing halogens, sulfur, phosphorous, nitrogen that may be present in the materials stream thus preventing formation of unstable compounds.

60. The apparatus of any of the preceding claims, further comprising removing residue of oxidized insoluble compounds out of the removal system during periodic maintenance if necessary.

61. The apparatus of any of the preceding claims, further wherein the oxidized insoluble compounds are converted to water-soluble compounds using any one of several chemical or electrochemical processes.

62. The apparatus of any of the preceding claims, further comprising a lid on the anolyte chamber and a basket in the chamber, wherein the materials are introduced into the basket in the anolyte chamber through the lid, wherein solid materials remain while the liquid portions of the materials flow through the basket into the anolyte, further comprising a lever connected to the lid for lowering the basket into the anolyte when the lid and the basket are closed such that all of the basket's contents are held submerged in the anolyte throughout the MEO process, and further comprising a seal around the opening of the lid and a locking latch for locking the lid before operation begins.

63. The apparatus of any of the preceding claims, further comprising a penetrator incorporated into the basket for creating multiple perforations in outer layers of the solid materials so that the anolyte can penetrate into the materials for speeding up oxidation of the solid materials by increasing surface areas exposed to the anolyte oxidizer and for allowing the oxidizer immediate access to portions of the materials that are encased in surrounding outer layers.

64. The apparatus of any of the preceding claims, further comprising a housing for accommodating the MEO apparatus.

65. The apparatus of any of the preceding claims, wherein the housing is an ultrasonic bath.

66. The apparatus of any of the preceding claims, wherein the MEO apparatus is integrated into a production process for destroying materials as a part of the industrial process.

67. The apparatus of any of the preceding claims, further comprising connecting pipes and pumps for connecting the MEO apparatus to the housing and/or the industrial process.

68. The apparatus of any of the preceding claims, further comprising a gaseous material supply system connected to the anolyte chamber for supplying gaseous materials in continuous feed operations, wherein the gaseous materials to be processed are pumped from the gaseous material supply into a pressure vessel, a regulator on the pressure vessel for controlling release of the materials into the anolyte chamber which contains the anolyte for destroying the gaseous materials.

69. The apparatus of any of the preceding claims, further comprising bubble heads for introducing the gaseous materials into the anolyte chamber assuring that the gas entering the gas stream is in the form of small bubbles to create a large surface area on which the anolyte acts to oxidize the gaseous materials.

70. The apparatus of any of the preceding claims, wherein the gaseous materials contact the anolyte in a counter current flow and wherein the gaseous materials are introduced into a lower portion of the anolyte chamber through the gaseous materials supply system, further wherein a stream of freshly oxidized anolyte solution directly from the electrochemical cell is introduced into the upper portion of the anolyte reaction chamber through an inlet tube enabling

the gaseous materials to continuously react with oxidizing mediator species in the anolyte as the gas rises up in the anolyte chamber past the downward flowing anolyte and wherein the gaseous materials reaching a top of the anolyte chamber has the lowest concentration of oxidizable species and is also in contact with the anolyte having highest concentrations of oxidizer species.

71. The apparatus of any of the preceding claims, further comprising baffles in the anolyte chamber for regulating progress of the gaseous materials through the anolyte in the anolyte chamber.

72. The apparatus of any of the preceding claims, further comprising a catholyte reservoir coupled to the catholyte chamber, the catholyte disposed in the catholyte reservoir.

73. The apparatus of any of the preceding claims, further comprising the catholyte reservoir being made from materials selected from the group consisting of metals, metal composites, fiberglass, glass, ceramics, and combinations thereof.

74. The apparatus of any of the preceding claims, further comprising surfaces of the catholyte reservoir being coated with materials selected from the group consisting of TEFLON™, glass, metal oxides, ceramic glazes, and combinations thereof.

75. The apparatus of any of the preceding claims, wherein the catholyte enters the catholyte reservoir from a tube connecting the electrochemical cell to the catholyte reservoir and wherein the catholyte exits the catholyte reservoir through a tube connected to the catholyte pump.

76. The apparatus of any of the preceding claims, further comprising an air intake and/or filter and air intake valve for introducing ambient air into the catholyte reservoir to dilute hydrogen gas formed at the cathode for catholytes through the air intake filter into the catholyte

reservoir, and wherein air mixed with catholyte off-gas exits out the tube to a catholyte off-gas handling system.

77. The apparatus of any of the preceding claims, further comprising an air sparge for introducing external air into the catholyte reservoir below the surface of the catholyte to prevent formation of hazardous off-gases by oxidation of the precursors back to the catholyte's stable composition.

78. The apparatus of any of the preceding claims, further comprising sensors including an ultrasonic sensor to measure catholyte solution levels in the catholyte reservoir, sensors to detect overfill due to water migration from the anolyte through the electrochemical cell to the catholyte solution.

79. The apparatus of any of the preceding claims, further comprising a dewatering tube for controlling levels of the catholyte by dewatering when levels exceed a set level by flowing the catholyte back through a dewater reject tube.

80. The apparatus of any of the preceding claims, further comprising a valve for controlling liquid flowing through the dewatering tube for the adding of returned catholyte or rejecting water makeup from a water storage tank.

81. The apparatus of any of the preceding claims, further comprising an ultrasonic source for promoting mixing and certain chemical reactions in the catholyte.

82. The apparatus of any of the preceding claims, further comprising AC and DC power supplies to drive the components in the apparatus and power cords connected to external power sources having voltages corresponding to overall power usage of the MEO apparatus.

83. The apparatus of any of the preceding claims, further comprising internal power supplies converting the AC power to DC power for internal usage and/or producing high current low voltage AC.

84. The apparatus of any of the preceding claims, further comprising further comprising a NEMA box pressurized with nitrogen gas for housing the power supplies and other electrical components for preventing hydrogen leaks that may result from sparks generated by the electrical equipment being used in the MEO apparatus.

85. The apparatus of any of the preceding claims, further comprising pneumatically controlled flow regulating valves for safety and for avoiding corrosion when in a hydrogen generation mode.

86. The apparatus of any of the preceding claims, further comprising a bulkhead isolated from the anolyte and the catholyte chambers and disposed there between for housing electrical components, an air intake and an exhaust port in the system, wherein air is forced into the compartment resulting in a slightly positive pressure preventing gases from other systems from entering the compartment.

87. The apparatus of any of the preceding claims, further comprising electrochemical cells having plate and/or frame filter press-type designs, electrodes stacked together in a vertical plane sandwich construction, ion selective semi-permeable membranes and/or spacers separating the electrodes and spacers, end plates held together by bolts that are torqued to the desired pressure to contain the electrolyte in its flow through the electrochemical cell.

88. The apparatus of any of the preceding claims, further comprising wherein all surfaces in the electrochemical cell that come into contact with the electrolyte, are made of material selected from the group consisting of polyvinylidene fluoride (PVDF), polypropylene

(PP), ethylene-chlorotrifluoroethylene (Halar), polytetrafluoroethylene (PTFE), and combinations thereof.

89. The apparatus of any of the preceding claims, further comprising an electrochemical cell comprising a box, a lid, and input and exit tubings through the lid to allow anolyte and/or catholyte to enter and exit respectively through the tubings to and from the electrochemical cell.

90. The apparatus of any of the preceding claims, further comprising wherein the box has a molded ceramic unibody construction and the lid is coupled to the box.

91. The apparatus of any of the preceding claims, further comprising nuts and bolts and clamp holes on the box and/or lid for coupling the lid to the box as well as providing easy access to interior of the electrochemical cell significantly improving the maintenance of the electrochemical cell.

92. The apparatus of any of the preceding claims, further comprising a gasket in the lid for creating a tight seal.

93. The apparatus of any of the preceding claims, further comprising glazed inside surfaces of the box and the lid to protect the ceramic walls from the oxidizer in the anolyte solution and the acids or alkaline in the catholyte solution.

94. The apparatus of any of the preceding claims, further comprising interior walls in the box for separating the anolyte from the catholyte.

95. The apparatus of any of the preceding claims, further comprising wherein some of the interior walls are ion selective semi-permeable membranes.

96. The apparatus of any of the preceding claims, further comprising electrodes including anodes and cathodes in slots in the ceramic walls and electrical connections to the electrodes passing through the lid to anode bus and cathode bus.

97. The apparatus of any of the preceding claims, further comprising the walls of the box having ridges and grooves to promote turbulent flow thereby reducing adverse boundary layer related phenomena at the anodes.

98. The apparatus of any of the preceding claims, further comprising oxidation resistant ion selective membranes bonded over interior walls serving as ceramic membranes for supplementing performance of the ceramic membranes.

99. The apparatus of any of the preceding claims, further comprising a plurality of electrochemical cells coupled together and having a pier box and lid.

100. The apparatus of any of the preceding claims, further comprising cell materials selected from the group consisting of fiberglass, polypropylene, metals, composite metals, and combinations thereof.

101. The apparatus of any of the preceding claims, further comprising interior surfaces having PTFE coating to protect the surfaces from oxidizers in the anolyte and acids or alkaline in the catholyte.

102. The apparatus of any of the preceding claims, further comprising the box and lid being composed of metal(s) and/or metal composites and the surfaces in contact with the electrolytes are coated with a glass glaze or metallic oxides.

103. The apparatus of any of the preceding claims, further comprising slots in the box for holding frames, wherein the frames receive and hold the membranes in liquid-tight manner to keep the anolyte and catholyte separated.

104. The apparatus of any of the preceding claims, further comprising porous electrodes so that electrolyte flows through the electrodes and contacts both sides of the electrodes.

105. The apparatus of any of the preceding claims, further comprising wherein separated cell containing the anolyte are connected by anolyte conduits in the wall of the electrochemical cell so that the anolyte solution flows through the entire electrochemical cell and wherein the cell containing the catholyte are connected by catholyte conduits in the wall of the electrochemical cell thereby enabling easy maintenance through ease of access to the interior of the box and to the membranes.

106. The apparatus of any of the preceding claims, further comprising platinum wires and/or miniature ORP electrodes in each chamber of the anolyte and catholyte chambers positioned such that the electrical potential may be measured between the chambers to provide information of the concentration of oxidizer in the anolyte chamber and also as an indicator of any leakage in the membrane.

107. The apparatus of any of the preceding claims, further comprising an oxidation reduction potential (ORP) sensor to control the level of oxidizer in the anolyte solution during operation of the MEO process, wherein when the anolyte is pumped by the anolyte pump from the anolyte system into the electrochemical cell the ORP detects level of oxidizer being produced by the electrochemical cell in exit streams from the electrochemical cell and the ORP data is sent through a signal conditioner to a PLC which uses an algorithm to calculate desired oxidizer concentration in the anolyte solution, and wherein the PLC issues commands that regulate the current from the power supply which provides the DC potential across the anode and cathode in the electrochemical cell.

108. The apparatus of any of the preceding claims, further comprising an advanced control system for regulating the oxidizer level uses a discharger to augment the algorithm as an additional control on the level of oxidizer in the anolyte.

109. The apparatus of any of the preceding claims, further comprising a discharger cell comprising two or more electrodes between which the anolyte flow is directed during the discharge process, wherein the discharger is introduced in the anolyte solution flow stream by opening a discharger input valve and a low voltage DC and/or AC electro potential is applied between adjacent electrodes, a DC/AC switch controls whether the voltage applied to the discharger DC or AC voltage, the voltage is selected so as to cathodically reduce the oxidizer species present in the anolyte without causing their production via anodic oxidation.

110. The apparatus of any of the preceding claims, further comprising wherein during operation of the discharger the DC voltage is not applied to the electrochemical cell and the DC power supply may provide the voltage to the discharger or two separate DC or AC power supplies, wherein the ORP measures the oxidizer species concentration both entering and leaving the discharger, and wherein the anolyte flows out of the discharger and returns to the anolyte chamber.

111. The apparatus of any of the preceding claims, further comprising an oxidizer suppression injection system in which the oxidizer species are suppressed by introduction of a benign material to another benign material with the concomitant reduction of the oxidizer species to its reduced state from a suppressor tank.

112. The apparatus of any of the preceding claims, wherein the suppressor material is injected into the anolyte in the anolyte chamber through a suppression injector up stream of the

injection valve, and wherein the suppression injection operation is initiated by an operator and is controlled through the programmable logic controller (PLC).

113. The apparatus of any of the preceding claims, further comprising simple/complex mediators usable singly, in combinations, as HPAs both singly and in combinations, and as mixtures of HPAs with simple/complex mediators, and electrolytes that are acid, alkaline, and/or neutral.

114. The apparatus of any of the preceding claims, further comprising a dewatering system having reverse osmosis (RO) units comprising a fluoropolymer/copolymer RO Unit having a membrane of a fluoropolymer/copolymer.

115. The apparatus of any of the preceding claims, wherein the fluoropolymer/copolymer membrane is used for dewatering of the anolyte by an RO unit when the oxidizer being used in the MEO apparatus would damage a membrane made from typical RO membrane materials and wherein cleaning of oxidizable material from the fluoropolymer/copolymer membrane is accomplished by the action of the oxidizer in the anolyte solution as it passes through the RO unit.

116. The apparatus of any of the preceding claims, further comprising a discharger comprising two or more electrodes between which the anolyte flow is directed during the discharge process is introduced in the anolyte flow stream, a discharger input valve is opened to allow the anolyte to enter the discharger, and a discharger output valve is opened to permit the flow of the anolyte leaving the discharger to flow through the sensor back to the anolyte chamber.

117. The apparatus of any of the preceding claims, further comprising low voltage AC or DC electro potential applied between adjacent discharger electrodes selected so as to

cathodically reduce the oxidizer species present in the anolyte without causing their production via anodic oxidation, wherein the low voltage discharges the oxidizers in the anolyte and the discharger provides electrons to the oxidizers when they are returned to their reduced form, an oxidation reduction potential (ORP) sensor senses the oxidized mediators in the anolyte being discharged which circulates through the discharger until the mediator oxidation potential reaches a pre-determined level.

118. The apparatus of any of the preceding claims, further comprising wherein after the discharging process is complete the discharger output valve opens to the RO pump and the discharged anolyte solution is processed through the RO membrane which is enclosed in the RO membrane housing, and wherein anolyte RO pressure is sensed by a pressure sensor.

119. The apparatus of any of the preceding claims, further comprising a multipass RO unit for a dewatering unit where the osmotic pressure head is so large that the pressure limit on the RO membranes may be exceeded or the membrane partition factor may be insufficient to affect the required degree of separation in a single stage, wherein the anolyte or catholyte is pumped by pumps through the RO membrane, RO tubes made out of the RO membrane fill insides of the RO membrane housing, and wherein a dilute solution of the electrolyte is used for lowering the osmotic pressure between the anolyte and catholyte.

120. The apparatus of any of the preceding claims, further comprising an anolyte sensor and/or catholyte sensor for sensing RO pressure by the degree of dilution.

121. The apparatus of any of the preceding claims, further comprising a dilute electrolyte reservoir for storing the dilute electrolyte which is pumped by a second stage anolyte pump or second stage catholyte pump as the tube side liquid enters into a RO membrane multipass housing.

122. The apparatus of any of the preceding claims, further comprising wherein osmotic pressure difference between the tube side liquid and the shell side pure water stream allows operation below pressure limits on the RO membrane.

123. The apparatus of any of the preceding claims, further comprising a water storage tank for storing pure water and a valve controlling supply of the water as needed to the dilute electrolyte.

124. The apparatus of any of the preceding claims, further comprising a RO unit rejecting to catholyte wherein the anolyte and the catholyte are similar in composition and the RO membranes tolerate the electrolytes, wherein excess water in the anolyte is rejected into the catholyte through the RO membrane, wherein the RO again uses the anolyte solution pumped by the pump as the tube side fluid in the RO membrane housing, and wherein the catholyte solution is pumped by the pump through the shell side.

125. The apparatus of any of the preceding claims, further comprising returning the anolyte and the catholyte leaving the housing to the anolyte and the catholyte chambers, respectively.

126. The apparatus of any of the preceding claims, further comprising a static RO unit wherein volume of the anolyte is relatively small and the flow rate through the RO membrane is low per unit area thus requiring greater flow area such that the total volume of the tubes required for this surface area exceeds the total anolyte volume.

127. The apparatus of any of the preceding claims, further comprising a valve opened to allow all the anolyte solution to be transferred from anolyte system through pump into the RO system tubes in the RO membrane housing.

128. The apparatus of any of the preceding claims, wherein the RO reservoir is pressurized to several thousand psi with air or nitrogen from the pressurized vessel and let stand until the dewatering has reached the desired goal.

129. The apparatus of any of the preceding claims, further comprising a regulator for controlling pressure in the RO system by releasing the air or nitrogen gas from the pressurized vessel until the desired pressure has been reached in the RO system and for holding that pressure until the dewatering is complete.

130. The apparatus of any of the preceding claims, further comprising a high pressure pump for pressurization of the RO system.

131. The apparatus of any of the preceding claims, further comprising a regulator for holding the anolyte under pressure in the RO membrane in the housing and/or a nitrogen pressure vessel for holding the catholyte under pressure with the catholyte RO pump.

132. The apparatus of any of the preceding claims, further comprising an osmotic cell wherein the anolyte and the catholyte have properties such that osmotic pressure drives water from anolyte side to catholyte side of the semi-permeable osmotic membrane.

133. The apparatus of any of the preceding claims, further comprising wherein the osmosis cell is pressurized on the anolyte side to increase flow and to dewater the anolyte by driving water from the anolyte to the catholyte.

134. The apparatus of any of the preceding claims, further comprising an osmotic cell with selected osmotic fluid wherein the catholyte has too low an osmotic pressure difference and the water in the anolyte will not cross the osmotic membrane, and wherein a second osmotic fluid with a higher osmotic pressure is provided to permit water to pass through the membrane.

135. The apparatus of any of the preceding claims, wherein the osmotic cell comprises two separate chambers wherein the anolyte and/or the catholyte flow along one side of an osmotic membrane and wherein another side of the osmotic membrane is in contact with an osmotic fluid having an osmotic pressure that allows water in the anolyte or catholyte to cross the osmotic membrane.

136. The apparatus of any of the preceding claims, further comprising an osmotic reservoir for storing the osmotic fluid, a pump for pumping the osmotic fluid from the osmotic reservoir through the osmotic cell and back to the osmotic reservoir.

137. The apparatus of any of the preceding claims, further comprising an osmotic valve for dewatering the anolyte or the catholyte by operating the valve to allow flow into the RO membrane housing containing the RO membranes.

138. The apparatus of any of the preceding claims, further comprising a storage tank for storing processed water passing through the membrane, wherein the stored water is available to be returned to either the anolyte or the catholyte or to be rejected from the MEO apparatus.

139. The apparatus of any of the preceding claims, further comprising a vacuum evaporation unit for removing water from the anolyte and/or catholyte vacuum evaporation.

140. The apparatus of any of the preceding claims, further comprising a particulate filter for passing the anolyte and/or catholyte solution exiting the apparatus to remove particulate matter.

141. The apparatus of any of the preceding claims, further comprising nanofilters for pretreatment of the materials to remove solids and soluble substances from the anolyte feed stream to the evaporator avoiding air-borne infectious release.

142. The apparatus of any of the preceding claims, wherein filtered anolyte and/or catholyte flows into the evaporator, and from the evaporator returns to the anolyte and/or the catholyte chambers and continue to circulate through the vacuum evaporator unit until excess water in the solutions are reduced to desired levels.

143. The apparatus of any of the preceding claims, further comprising a vacuum pump for reducing pressure in the evaporator system to less than a vapor pressure of water in the anolyte and/or catholyte at their respective temperatures, and a condenser connected to the system wherein water evaporates and progresses into the condenser.

144. The apparatus of any of the preceding claims, further comprising wherein pressure in the evaporator condenser system is controlled by vapor pressure of water at the condenser temperature.

145. The apparatus of any of the preceding claims, further comprising an anolyte chiller and/or a catholyte chiller for flowing chilled solution through a condenser jacket and returning to the anolyte chiller and/or the catholyte chiller, respectively.

146. The apparatus of any of the preceding claims, further wherein heat removal in condenser coils results in water vapor condensing in the coils, wherein water flows from the condenser through a condenser cold leg where it is exhausted by the vacuum pump and is allowed to exit the water reservoir through a water reservoir valve when water in the reservoir has reached a predetermined water level along with any gas present in the anolyte and/or the catholyte.

147. The apparatus of any of the preceding claims, further comprising a controller system comprising computing devices including automated programmable logic controllers (PLCs) coupled to pneumatic controls and system sensors for monitoring the process performed

by the MEO apparatus, displaying data and status information on a monitor relative to the monitoring, executing operational cycles in the MEO apparatus, providing methodology to change parameters in the MEO process through digital control over system components including flow control of the anolyte and the catholyte, electrochemical cell power, off-gas systems, ultraviolet and ultrasound systems.

148. The apparatus of any of the preceding claims, further comprising storing on the PLC default values for typical parameters such as percent pump flow rate, anolyte and catholyte volume capacity, anolyte and catholyte temperatures, valve operation and sequencing, enabling and disabling of RO dewatering, water makeup in the anolyte and catholyte systems, ultrasonic and ultraviolet source operations, off-gas temperatures, and enabling and disabling the data logging.

149. The apparatus of any of the preceding claims, further wherein the controller system comprises methodology to monitor and change the MEO parameters including numerous mediator and electrolyte combinations, and wherein the controller system maintains a record of operation of the MEO apparatus for post operation analysis using data recorded in the data logger.

150. The apparatus of any of the preceding claims, further comprising a display including a touch screen monitor for providing an operator of the MEO apparatus with options for running the apparatus, for displaying status of each component in the MEO apparatus based on the information received from the sensors including state of the oxidation process to directly evaluate the data from the sensors on the monitor, and instrumentation processed through a signal conditioner, for measuring activity of redox couples using an oxidation reduction potential (ORP) sensor located throughout the MEO apparatus.

151. The apparatus of any of the preceding claims, further comprising using the ORPs and sensors measuring the CO_2 to develop an algorithm to calculate state of the oxidation process in the MEO apparatus.

152. The apparatus of any of the preceding claims, further comprising connections for connecting the controller to the internet and to other operators for real-time interactive sensing, analyzing, monitoring, viewing, and controlling all parameters and components of the MEO apparatus.

153. The apparatus of any of the preceding claims, wherein the connections are connections to the internet, phone line, cell phone, personal computer (PC), and other media devices.

154. The apparatus of any of the preceding claims, further comprising a data logging system for recording sensor data used to assess performance and past use of the system for viewing remotely or on-site.

155. The apparatus of any of the preceding claims, wherein the controller system provides information to diagnose problems associated with the MEO apparatus.

156. The apparatus of any of the preceding claims, further comprising microprocessors or multi-position cyclic timer switches.

157. The apparatus of any of the preceding claims, further comprising an off-gas system for processing off-gas from the anolyte reaction chamber from complete and incomplete combustion of the material including carbon-dioxide, oxygen from oxidation of water molecules at the anode and possibly small amounts of low molecular weight hydrocarbons from incomplete combustion that are gases at the anolyte operating temperature and pressure.

158. The apparatus of any of the preceding claims, further comprising real time monitoring of the off-gas processing system with a gas detector sensor.

159. The apparatus of any of the preceding claims, further comprising an exhaust for exhausting the off-gas extracted by air flow through the anolyte chamber and catholyte chamber.

160. The apparatus of any of the preceding claims, further comprising an exhaust fan in the exhaust for drawing ambient air into the anolyte chamber through the anolyte air intake/filter and into the catholyte chamber through the catholyte air intake/filter.

161. The apparatus of any of the preceding claims, further comprising a sail switch for sensing flow of the off-gas.

162. The apparatus of any of the preceding claims, further comprising an anolyte demister wherein reaction products resulting from the oxidation in the anolyte system are discharged through the anolyte off-gas exit tube to the anolyte demister.

163. The apparatus of any of the preceding claims, further comprising an anolyte chiller, wherein the anolyte demister is cooled by the anolyte chiller.

164. The apparatus of any of the preceding claims, wherein easily condensed products of incomplete oxidation are separated in the anolyte demister from the anolyte off-gas stream and are returned to the anolyte chamber or the anolyte reservoir through an anolyte condensate return tube for further oxidation.

165. The apparatus of any of the preceding claims, further comprising a dump valve connecting the anolyte chamber and the anolyte reservoir allowing for the anolyte and contents of the anolyte reaction chamber to be stored in the anolyte reservoir.

166. The apparatus of any of the preceding claims, further comprising a gas cleaning system for reducing non-condensable incomplete oxidation products to acceptable levels for

atmospheric release after the anolyte off-gas is contacted in a counter current flow gas scrubbing system in the gas cleaning system, wherein the noncondensables from the anolyte demister are introduced into the lower portion of the column through a flow distribution system of the gas cleaning system and a small side stream of freshly oxidized anolyte direct from the electrochemical cell is introduced into the upper portion of the column resulting in the gas phase continuously reacting with the oxidizing mediator species as it rises up the column past the down flowing anolyte.

167. The apparatus of any of the preceding claims, further comprising a catholyte off-gas handling system for drawing ambient air through the catholyte reservoir and through the catholyte off-gas exit tube to a catholyte demister by the exhaust fan, wherein water vapor in the air stream is condensed in the catholyte demister by the coolant from the catholyte chiller and the condensate returns to the catholyte reservoir through the catholyte condensate return tube.

168. The apparatus of any of the preceding claims, further comprising a nitrogen gas system comprising a nitrogen gas bottle having a gas valve for opening and closing the nitrogen gas bottle, wherein the gas value is closed when the nitrogen gas bottle is being removed from the MEO apparatus and when the gas valve is opened a nitrogen pressure regulator controls the nitrogen gas pressure to the nitrogen gas system, and wherein the nitrogen gas pressure regulator is controlled by commands from the PLC.

169. The apparatus of any of the preceding claims, wherein the nitrogen gas system is used to purge the catholyte reservoir if hydrogen gas exceeds a two percent level in the off-gas handling system.

170. The apparatus of any of the preceding claims, further comprising a catholyte reservoir purge regulator which is opened by a command from the PLC allowing nitrogen gas to

flow and/or to purge the catholyte reservoir and a catholyte reservoir purge valve closes the catholyte air sparge so that the nitrogen purges the catholyte reservoir.

171. The apparatus of any of the preceding claims, wherein the nitrogen gas system provides gas pressure to power the valves in the anolyte and catholyte systems, wherein the nitrogen instruments enable valve to open by command from the PLC to provide nitrogen gas pressure to instruments and actuators in the MEO apparatus and wherein the nitrogen gas pressure is regulated to the instruments by the instrument nitrogen pressure regulator and to the actuators by the actuator nitrogen pressure regulator.

172. The apparatus of any of the preceding claims, further comprising a hydrogen gas system wherein the catholyte solution enters the catholyte reservoir from the electrochemical cell and returns from the catholyte reservoir through the catholyte pump to the catholyte system and hydrogen exits the catholyte reservoir and the amount of hydrogen is detected by a hydrogen gas detector, wherein the hydrogen off-gas passes through a catholyte demister, and chilled coolant flows from a catholyte chiller to the catholyte demister and returns to the catholyte chiller.

173. The apparatus of any of the preceding claims, wherein the hydrogen gas is not collected for further use and is diluted by air entering the catholyte reservoir through the catholyte air intake filter when the catholyte air intake valve is in the open position, wherein the hydrogen selection valve is positioned by commands from the PLC to exhaust the diluted hydrogen through the exhaust fan to the off-gas vent.

174. The apparatus of any of the preceding claims, further comprising a hydrogen gas detector for monitoring the hydrogen to insure percentage of hydrogen is at or below the regulated safe level and a sail switch to monitor the flow through the exhaust fan to ensure the flow is adequate.

175. The apparatus of any of the preceding claims, wherein the hydrogen gas is collected for use by either a fuel cell system or a combustion system such as a water heater, wherein the catholyte air intake valve is in the closed position, the hydrogen selection valve is in the position to pass the hydrogen gas to hydrogen gas pump which compresses the hydrogen which passes through a hydrogen gas regulator, a hydrogen sensor measures the percentage of hydrogen gas flowing to the hydrogen gas regulator, compressed hydrogen is stored in a pressurized hydrogen storage bottle and hydrogen is released through the hydrogen regulator to devices in use.

176. The apparatus of any of the preceding claims, wherein hydrogen gas is captured by zirconium or Ziralloy getters, and wherein the hydrogen gas is absorbed by the getters for later disposal.

177. The apparatus of any of the preceding claims, wherein the MEO apparatus may be operated in either full automatic or manual modes including waste destruction cycle used for destruction or oxidation process, solids removal cycle used to remove any solid residuals, the ABORT Cycle used to stop the MEO process when necessary, cleaning and disinfection cycle used to sterilize/disinfect objects and equipment, MANUAL cycle which enables a full diagnostic and data analysis capability.